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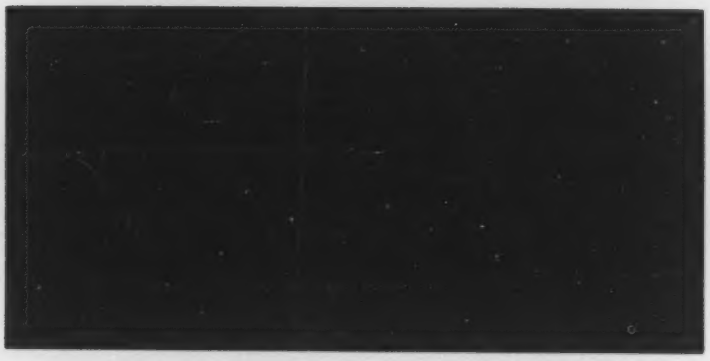

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THE POTENTIAL IMPACT OF TECHNOLOGY ON THE SKILL REQUIREMENTS OF FUTURE JOBS

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Abstract

This paper assesses the potential impact of technology on the skill requirements of future jobs. The paper first explores some of the theoretical and methodological issues surrounding the topic of skill requirements. Then it examines the impact of past technologies on skill requirements. Changes in the skill requirements of jobs result from changes in the skill requirements of individual occupations and from shifts in the composition of jobs in the economy. In the past, technology tended to reduce the skill requirements of jobs, while the changing composition of jobs favored more skilled occupations. In the future, technology will continue to lower the skill requirements of many occupations, while future job shifts will not favor more skilled occupations. Some of the implications of this future scenario are discussed.

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> Technological change and global competition make it imperative to equip students in public schools with skills that go beyond the 'basics.' For productive participation in a society that depends ever more heavily on technology, students will need more than minimum competence in reading, writing, mathematics, science, reasoning, the use of computers, and other areas.
>
> Task Force on Education for Economic Growth
> Education Commission of the States

There is a widespread belief in the United States that the application of new technologies in the workplace is raising the average skill requirements of jobs. In order to better prepare students for the demands of their future work roles, a number of influential commissions have called for sweeping improvements in the nation's schools. They caution that a failure to meet this challenge will not only limit students' opportunities in the future labor market, but it will threaten the U.S. competitive position in the growing world marketplace.

New technological innovations, spurred by the revolution in microelectronics, are appearing with increasing frequency in the marketplace. New generation microcomputers are leading the way. As these machines become smaller, cheaper, and more powerful, they are being used in a wide variety of jobs throughout the economy. Some experts believe that half of all American workers will be using some sort of computer device in the their jobs by the end of the decade (Giuliamo 1982, p. 152). But will the increased use of these more sophisticated technologies require workers with more sophisticated skills?

While most people believe that workers will need increased skills to deal with these new technologies, two kinds of evidence challenge these beliefs. First, studies of recent applications reveal that in many cases new technologies can actually lower the skills required in jobs, not raise them. Second, technology affects the average skill requirements of jobs through its impact on the distribution of jobs in the economy as well as the skills of individual occupations. Recent employment forecasts suggest that future job growth will favor low-level clerical and service occupations. So even if technology raises the

skill requirements of some occupations, it could still lower average skill requirements of jobs in the economy by favoring employment growth in low-skilled occupations.

The impact of technology on skill requirements of jobs in the future may be quite different than its impact in the past. Older technologies greatly reduced the physical demands of work. Employment for laborers, for example, declined from 30 percent of the work force in 1900 to less than 6 percent in 1970. During the same period employment in more skilled professional and technical jobs increased from 4 percent to 14 percent (U.S. Bureau of the Census 1975, Table D 182-232). Future technologies will further reduce the physical demands of work, but they will also be able to reduce the mental demands of work. New information technologies not only can store and process large amounts of information, they can exercise judgement through complicated, decision programs. As these technologies become more complex and sophisticated, they will be capable of performing more complex and sophisticated mental tasks.

Whether technology lowers or raises skill requirements of jobs in the future has important ramifications for education and the economy. If technology does reduce the skill requirements of jobs, then current efforts to improve education and upgrade the skills of future workers may prove to be dysfunctional. A growing number of students may find that their increased educational competencies are not required in the workplace. Already, a sizeable portion of the American workforce has more education than their current jobs require (Rumberger 1984a). Raising educational attainments at a time of decreasing or even steady skill requirements could further increase this imbalance. And recent evidence suggests there could be a sizeable cost to this imbalance through reduced worker effort and productivity (Tsang 1984). Increased educational attainments in the face of reduced skill requirements could actually impair economic performance in the future.

At the moment, however, it remains unclear whether technology will raise or lower the average skill requirements of future jobs. Research

cannot predict what the impact of future technologies will be. Studies of past technologies are suggestive. But in general, little empirical research has addressed the issue of skill requirements. Little theoretical discussion has been devoted to this topic as well.

The purpose of this paper is to assess the potential impact of technology on the skill requirements of future jobs. The first section of the paper will examine some of the theoretical and methodological issues surrounding the topic of skill requirements and the influence of technology. The next section will review some empirical studies that have attempted to assess the impact of past technologies on skill requirements of jobs. The following section will then speculate on the likely impact of new technologies on future job skills. The final section of the paper discusses some of the implications of this future scenario.

The Study of Skill Requirements

Scholars from a variety of academic disciplines, including economics, sociology, and industrial psychology, have long been interested in the study of skills. Most of this attention, however, has focused on the skills that workers bring into their jobs, measured by education and training, rather than the skill requirements of jobs themselves. In fact, skill requirements associated with jobs are not recognized or treated in neoclassical economic theory. As a result, literature that examines the impact of technology on the skill requirements of jobs is rather limited and generally falls outside the neoclassical paradigm.

Theoretical Issues

Human capital theory, the principle paradigm in neoclassical economics, recognizes skills only as characteristics of individuals and generally analyzes them indirectly, through their association with education. As Becker, one of the principle architects of this view, points out: "education has little direct effect on earnings; it

operates primarily indirectly through the effect on knowledge and skills" (Becker 1964, p. 86). In this view, education either develops skills that are valued in the workplace, or simply identifies persons with these skills (Spence 1973; Taubman and Wales 1974).

The reason that skills are only associated with individuals is found in the tenets of neoclassical theory. According to this view, skills, in the form of human capital, are treated like physical capital. In order to maximize profits, firms hire each factor of production until the value of its marginal product equals the cost of hiring it, given available techniques of production and market prices. The wage paid to each category of skilled labor, therefore, equals the value of its productivity to the firm. It is assumed that the skills possessed by workers are fully utilized by the firm since employers can readily shift factors of production to respond to changing factor prices or production techniques.

In reality, of course, employers may be unable or unwilling to fully utilize the skills of their workers. Interestingly, neoclassical economists acknowledge that physical capital may not be fully utilized in all instances and have developed the concept of capacity utilization to measure this discrepancy. But they do not acknowledge that, in a similar manner, human capital may not be fully utilized as well. Yet organizational theorists and industrial psychologists have long argued that a variety of factors may prevent the full utilization of workers' skills (Rumberger 1983). These factors include the way work is organized in the firm, particularly the designation of tasks into jobs.

Neoclassical theory also offers little insight into how technology will affect the demand for skills. Technology is generally treated as an exogenous factor in the production process. So little attention has been given to the issue of substitution between human and physical capital. Some view physical and human capital as complementary: more complex skills enable workers to better use more complex technologies in the firm (Nelson and Phelps 1966). Yet little empirical research exists to support these notions.

The concept of skills as characteristics of jobs and the impact of technology on skill requirements have been treated in other economic paradigms and by other academic disciplines.

It is the notion of jobs that gives rise to the concept of skill requirements. Jobs identify sets of tasks that individuals perform in the workplace. Scholars from a variety of disciplines have studied a number of characteristics associated with jobs. Sociologists have concentrated on occupational status or prestige (e.g., Spaeth 1979; Granovetter 1982). Some economists have examined occupational differences in earnings as well as nonpecuniary rewards associated with jobs (Eckaus 1973; Duncan 1976). Industrial psychologists have identified a wide number of physical and social characteristics of jobs that affect productivity and behavior in the firm (e.g., Vroom 1964).

One important characteristic of every job is the set of skills that workers require to perform the tasks associated with it. This concept recognizes the distinction between the skills that workers bring into their jobs and the skills that their jobs require. The two may not be the same. Employers can raise the hiring requirements of a job because of changes in the available supply of job applicants without changing the tasks or duties associated with the job. They may prefer workers with more education simply because it reduces the costs of training them in the specific skills that their jobs require (Thurow 1975). And because the allocation of workers to jobs depends on available supplies of workers and jobs, workers may actually possess more skills than their jobs require. Moreover, if the distributions of skills associated with workers and jobs fail to move in the same direction, then discrepancies between these two measures of skills could increase over time.

It is generally assumed that the skill requirements of jobs have increased over time simply because new technologies have helped to transform the economic base of the country, creating new, more skilled jobs in the process. The earlier transformation of the U.S. economy from agriculture to manufacturing—spurred by technical developments in power generation, communications, transportation, and industrial

machinery-created new jobs for skilled production and professional workers. The more recent transformation from manufacturing to service, brought about by developments in electronics, communications, and transportation, have created new jobs for professional and technical workers. To economists, these technical developments have increased the demand for education and both have contributed to past economic growth in the United States (Denison 1979).

One of the most compelling challenges to the prevailing view that skill requirements have increased over time has been offered by Harry Braverman (1974). Braverman argues that employers attempt to fragment work tasks into simpler components, thereby deskilling jobs, for two important reasons: to lower their costs and to better control the work process. The economic incentive for lowering skills was first recognized by Adam Smith in the Wealth of Nations and later refined by Charles Babbage more than 150 years ago:

> That the master manufacturer, by dividing the work to be executed into different processes, each requiring different degrees of skill or of force, can purchase exactly that precise quantity of both which is necessary for each process; whereas, if the whole work were executed by one workman, that person must possess sufficient skill to perform the most difficult, and sufficient strength to execute the most laborious, of the operations into which the art is divided (quoted in Braverman 1974, pp. 79-80).

Braverman argues that "...Babbage's principle eventually becomes the underlying force governing all forms of work in capitalist society, no matter in what setting or at what hierarchical level" (Braverman 1974, pp. 81-82). The principle architect of scientific management, Frederick Taylor, also recognized the economic gains from fragmenting tasks into less skilled components and using "men who are of smaller calibre and attainments, and who are therefore cheaper than those under the old system" (quoted in Shaiken forthcoming, p. 19).

Employers long have recognized and responded to this economic incentive. Henry Ford saw the value of using low-wage, low-skilled workers to perform some of the tasks associated with automobile assembly

more than 80 years ago (Gartman 1979, p. 196). Today builders employ less skilled workers at lower wages to prefabricate portions of homes in order to reduce labor costs (San Francisco Examiner 1982).

Technology can further this process of fragmentation. After work is fragmented into discrete tasks, some of the tasks can be performed by machine. Henry Ford first fragmented the tasks associated with automobile manufacturing into an assembly line process, and then later mechanized certain tasks, such as the movement of cars along the line (Gartman 1979, p. 200). As technology becomes more sophisticated, machines can perform a greater number and more complex tasks. In modern automobile plants, robots weld and paint cars as well as perform a variety of other tasks.

But whether technology reduces skills depends on what tasks are mechanized and what new tasks are created by the use of new machines. Many people believe that machines are used primarily to perform the least skilled tasks and that to use more complex machines workers require more complex skills. Yet employers can achieve greater cost savings by mechanizing complex tasks performed by high-wage labor than by mechanizing simpler tasks performed by low-wage labor. In other words, General Motors has more incentive to replace high-wage automobile workers with robots than McDonalds has to replace workers who earn minimum wages.

Similarly, the easier new machines are to operate, the lower the wages employers have to pay someone to use them. Manufacturers therefore deliberately design machines that require less skill to operate (Shaiken forthcoming, Chapter 3). And by using such machines, employers can reduce their labor costs. The management of the National Broadcasting Company, for example, recently argued to their workers' union that the new computer-driven videotape machines are so sophisticated that they can be operated by lower-wage, nonunion workers (Business Week 1984a, p. 71).

Technology also affects the skill requirements of jobs through its influence on the number and types of jobs available in the economy. The

development of new technologies creates new jobs in the firms that manufacture them as well as new jobs in firms where they are employed. Technology also eliminates jobs. But what is the net impact of this process? Are more jobs created by technology than eliminated? Are the jobs created generally more skilled than the jobs destroyed? Although current research fails to provide definitive answers to these questions (Rumberger 1984b), evidence reviewed below does suggest some answers.

Measuring Skill Requirements

In order to determine the impact of technology on the skill requirements of jobs, it is necessary to develop measures of skill requirements. But the nature of job skills makes this task very difficult: skills vary widely by level and type, they change over time, and they can vary widely between firms.

Researchers have identified a number of different skills and personal characteristics that contribute to effective work performance. These include cognitive skills, physical or motor skills, communication skills, attitudes, and personality traits (Peterson and Bownas 1982). Some skills are general and can be applied to a wide variety of work settings. Other skills are specific in that they can only be applied in a limited number of work settings or firms (Becker 1964). Skills also vary by level. Higher-order, complex skills require more time to learn than the mastery of simpler, lower-level skills.

Since a wide variety of skills are used in the workplace, it is difficult to develop appropriate measures that can identify each type. To identify the skills of workers, researchers frequently rely on one or two proxy measures, such as education or years of experience, that fail to capture either qualitative or quantitative differences in skills. Educational credentials, for example, reveal little about how much or what kind of learning took place in school and hence what skills were developed. The skill requirements of jobs are even more difficult to measure. Not only is it important to identify the various kinds and

levels of requisite skills, the requirements need to be assessed independently of the skills possessed by the workers holding those jobs.

Another difficulty in trying to measure skills is that they can change over time. The introduction of new technologies can create new jobs and change the skill requirements of existing jobs. The more rapidly these changes come about, the more skill requirements are likely to change. This presents a serious problem in assessing skill requirements of new technologies since they are being developed and applied with greater frequency throughout the current labor market.

Finally, skill requirements can vary widely according to the organization of firms (Levin 1982). Even seemingly standard jobs, such as computer programmer or machinist, can have different duties in different firms. The impact of technology on job skill requirements will also depend on the way work is organized in response to these technologies. All firms may not respond in the same way.

These characteristics of skills make research on skill requirements of jobs exceedingly difficult to perform. Just the large number of different jobs that exist makes a comprehensive assessment of skill requirements for the overall economy almost impossible. In the United States, the Department of Labor does attempt such an assessment through The Dictionary of Occupational Titles. Conducting field assessments in a sample of firms every 10 to 12 years, the Labor Department measures a number of cognitive skills that workers require to perform their jobs. The latest survey was published in 1977 and covers approximately 20,000 jobs (U.S. Department of Labor 1977). These surveys have been used to measure the distribution of skill requirements in the U.S. economy and changes in skill requirements over time (Spenner 1979; Rumberger 1981a). But the data are difficult to use and do not overcome all the difficulties outlined above (Miller et al. 1980).

Although assessing the skill requirements of jobs and the impact of technology on them is extremely difficult at an aggregate level, research on particular occupations and industries has addressed these issues. These studies, which are reviewed below, provide some insight

into the possible impact of new technologies on the future skill requirements of jobs.

The Past Impact of Technology

Past technologies have altered the tasks and skill requirements in a wide range of jobs throughout the U.S. economy. Technology has also helped to alter the distribution of jobs in the economy. Have these two impacts raised or lowered the average skill requirements of jobs?

The Skill Requirements of Jobs

Studies of a wide range of occupations suggest that past technologies have often reduced the skill requirements of jobs in both the factory and the office. These studies also reveal that the application of technologies takes place in conjunction with the process of job fragmentation: jobs are fragmented into a series of tasks and then some of the tasks are performed by machine. Together these two processes have eliminated jobs, increased managerial control, and lowered skill requirements.

The printing industry is one area where deskilling has taken place. As the printing industry developed, the work associated with the printing process was fragmented into a number of highly specialized components, including typesetting, makeup, photoengraving, and presswork. New technologies first began to displace many of the physical tasks associated with this work and then many of the mental tasks. In the typesetting operation, for example, linotype machines and later teletypesetting machines removed the physical work involved in setting metal type. Then the computer removed the mental skills associated with word hyphenation and line justification. Finally, phototypesetting eliminated the use of metal type altogether and, along with computer word processing, completely destroyed the traditional craft of typesetting. Other technological advances have reduced the skill and labor requirements in other areas of the printing process (Zimbalist 1979; Wallace and Kalleberg 1982).

Skill requirements of jobs were also lowered in factories. During the 1950s American factories began to automate many aspects of production. Union leaders worried that many jobs would be lost and that unemployment would rise. Others worried that automation would eliminate low-skilled employment opportunities. James Bright, a professor at the Harvard Business School, examined the effects of automation on the skill requirements of jobs in a wide variety of manufacturing firms. Contrary to widespread opinion, Bright observed that the skill requirements of jobs first increased with the introduction of new technologies, but later decreased as these technologies were refined (Figure 1):

> Automated machinery requires less operator skill, or at least not any more skill, after certain levels of mechanization are passed. It appears as though the average worker can more quickly and easily master new and different jobs where highly automatic machinery provides the skill, effort, and control required. Furthermore, some "key" skilled jobs, currently requiring long experience and training, are reduced to easily learned machine-tending jobs (Bright 1958, pp. 176-177).

One important technological development in the factory is the numerical controlled (NC) machine tool. NC machine tools redefine the tasks and hence the skill requirements of machinists. With traditional machines tools, machinists would determine how to machine a part and then produce it. With NC, the planning or "how to" function was separated from the execution function. Programmers would determine how to produce a part through a series of numerical machine codes, so machinists would simply have to feed the machine and respond to any problems that arose. As a result, the "skill" of the machinist was transferred to the machine. More recent developments have now automated the tasks of programming, further reducing the skills required in machining. Although NC has had less affect on the practice of machining than one might expect because of both technical and social difficulties, it still provides an important illustration of how employers and machine

designers have attempted to lower skills and reduce costs on the factory floor (Shaiken forthcoming, Chapter 4).

Deskilling has taken place in the office as well as the factory. As large offices evolved in the late nineteenth century, office work was divided along hierarchical lines, with relatively few managerial workers performing the mental work and a large cadre of clerical workers performing the manual tasks (Glenn and Feldberg 1977). Clerical work was fragmented into a large number of specialized occupations—typist, switchboard operator, receptionist, file clerk, duplicating machine operator--with low-wage workers performing the least-skilled jobs. Office machines furthered the process of fragmentation. New word processing equipment made typing pools more cost-effective and allowed managers to better control the "paper production" process. Machines were also able to displace some of the more skilled clerical jobs. Dictating machines, for example, have largely eliminated jobs for skilled stenographers.

The computer field provides one final illustration of skill displacement. Early computer programmers had to know as much about the capabilities and applications of hardware as the software or coding language. As computers became larger and more powerful, programming was fragmented into a number of discrete occupations requiring widely different skills: systems analysts designed large-scale software, programmers wrote the instructions, and keypunch operators coded the information. Increased memory capacity and other technical improvements allowed the development of more sophisticated languages and "canned" packages that further simplified the job of programming (Kraft 1977; Greenbaum 1979). Recent developments have reduced the labor requirements associated with computers as well: new generation microcomputers and "user-friendly" software require neither programmers nor operators.

These case studies suggest that, at least in some areas of work, past technologies have been used to lower skill requirements and reduce wage costs. Studies done at a more aggregate level suggest little

change in the average skill requirements of jobs (Spenner 1979; Rumberger 1981a). Overall this evidence challenges the widely held view that technology tends to raise skill requirements.

The Composition of Jobs

Fragmentation and technology affect the distribution of skills within industries by creating new occupations and altering the skill requirements of existing ones. But the distribution of skills in the overall economy also depends on the distribution of employment among industries. Since different industries have different occupational mixes, employment shifts among industries can significantly alter the skill requirements of jobs in the economy independently of skill changes that occur within industries. Two factors have altered the distribution of employment among industries over this century: 1) changes in the demand for goods and services; and 2) differences in productivity and productivity growth among industries.

Consumer spending patterns have shifted towards increased purchase of services. In 1940, for example, 39 percent of personal consumption expenditures went for services, whereas in 1980, 47 percent went for services (U.S. Council of Economic Advisors 1984, Table B-2). Other components of demand—investment, imports and exports, and government purchases—have also shifted. As a result, some sectors of the economy, primarily those in the services-producing area, have grown much faster than others (Table 1).

Differences in productivity and productivity growth rates have also affected employment patterns. In manufacturing, for example, economic output increased 213 percent between 1947 and 1981, the same rate of growth as the economy overall (Table 1). Yet employment only increased 30 percent because of improvements in productivity. In contrast, employment growth in services equaled the growth in economic output from that sector because productivity remained constant over this period. In agriculture, economic output increased 65 percent over this period, while employment declined by 60 percent. Different productivity levels

among industries also mean that two industries with similar economic growth rates will produce different employment growth rates.

Because the composition of jobs varies so widely among industries, changing patterns of employment among industries have greatly altered the composition of jobs in the economy. Employment growth among major occupation groups for 20 year intervals since the beginning of the century are displayed in Table 2. These data document a number of important trends. First, they show the decline in agricultural employment that has occurred throughout this century. Second, they show the growth of employment within service occupations. Third, they show the growing importance of white-collar employment.

It is difficult to infer from these data whether employment shifts have favored higher or lower skilled occupations. The reason is that occupational titles reveal little about actual skill requirements of jobs. Many people suppose that the shift from blue-collar to white-collar employment suggests an increase in the average skill requirements of jobs. Yet jobs in the office have been subject to the same process of fragmentation and deskilling as jobs in the factory. So the labels "white-collar" and "blue-collar" actually reveal little about job content or requisite job skills. Moreover, the skills of particular jobs within major occupation groups vary quite widely (Rumberger 1981a, Table 2).

Despite these limitations, employment shifts, at least in recent years, do appear to have favored more skilled occupations. In the 1960-80 period, professional and technical jobs increased by 8.5 million, compared to an increase of 2.1 million clerical jobs. This contrasts with earlier periods where clerical employment increased more than professional and technical employment. The decline in employment for laborers and farm workers (many of whom are laborers) also suggests a general upgrading of the skill requirements of jobs in the economy.

While the case studies reviewed above suggest that at least some jobs in the economy have been deskilled, employment shifts suggest a

general upgrading of jobs. What has been the net increase of these two factors?

One recent study suggests that the distribution of skills in the U.S. economy have actually narrowed as a result of these two factors. Rumberger (1981a), using data from the two most recent editions of The Dictionary of Occupational Titles, examined changes in the distribution of skills in the U.S. economy between 1960 and 1976. He found that changes in the distribution of jobs in the economy did, indeed, favor more skilled occupations. Yet changes in the skill requirements of individual jobs tended to reduce skills at the high end as well as the low end of the distribution. The net result of these changes was to increase skill requirements in the middle and upper-middle range of the skill distribution and reduce skill requirements at the upper and lower ends of the distribution (Table 3).

The Future Impact of Technology

The skill requirements of jobs in the future economy will also depend on changes in the skill requirements of jobs and on shifts in the composition of jobs in the economy. Technology will influence both.

The Skill Requirements of Jobs

There is little doubt that technology will have a widespread and profound impact on work in the future. More and more people will be using computers in their future jobs. Computers have already changed the way work is performed in virtually every sector of the economy, from agriculture to design (Scientific American 1982). As new, more sophisticated applications are developed, they will be applied to more and more jobs.

But how the increased use of computers and other sophisticated devices affects the skill requirements of jobs will depend on two factors: 1) the technical capabilities of the technologies, and 2) how the technologies are actually employed in the workplace. The technical capabilities, in turn, will depend on the number and range of tasks that

new machines will be able to perform. Past technologies were limited to performing relatively simple physical and mental tasks. In some cases the technology failed to perform as well as expected and thus had less affect on skills than originally anticipated (Shaiken forthcoming, Chapter 4). But future technologies, based on incredible advances in microelectronics, are likely to be more reliable and will be able to perform a greater variety of more complex physical and mental tasks. As technology advances, more tasks will be able to be performed by machines and, as a result, more worker skills displaced. Several recent technologies illustrate the potential skill displacement of modern machines.

The modern cash register provides one simple illustration. Cashiers at McDonalds simply press the keys on the machine corresponding to each item. The machine recalls the prices of the items, calculates the total bill, including the tax, and determines the amount of change after the cashier enters the denomination of the customer's bill. Thus cashiers no longer have to be able to add and subtract because the machine performs these functions. New scanning devices in supermarkets only require cashiers to pass items over a scanner that reads the barcode on the product, records the price, and even keeps a record of all sales for reordering purposes. These advances have reduced the requisite skills for cashiers.

Current word processors reduce the need for letter-perfect typing skills because corrections can be made easily on the screen before a hard copy is produced. New systems can now correct spelling mistakes and even grammatical errors. Thus the need for traditional secretarial skills is reduced. At the same time, little more skill is needed to use these machines than traditional typewriters and the skills are easily learned. As word processing software has become more sophisticated, it has become even easier to use or more "user-friendly." Apple, the manufacturers of the new-generation Lisa and MacIntosh computers, claim that they can teach first-time users to perform a series of office functions after 30 minutes of instruction.

These devices represent the current state of technology. But the power of the computer promises more sweeping and much more sophisticated applications in the future. The center of this development work is in the area of artificial intelligence or simply AI. Artificial intelligence is concerned with the development of computer systems that can mimic the functions of the human mind, including sensing, speaking, storing and retrieving information, reasoning, and even learning. Although computers have a long way to go before approaching the capabilities of humans, researchers in AI have long recognized this potential. As one AI expert recently said: "Anything--anything--humans can do, artificial intelligence can do" (San Jose Mercury 1984).

That potential has already been demonstrated in a number of new applications called expert systems. Expert systems are computer programs that perform like human experts: they take information on current conditions, draw on a vast reservoir of knowledge, and make judgments based on this information and knowledge. Thus they are able to perform high-level, complex mental tasks that traditionally have been the domain of the most desirable and highly-paid workers in the economy: professional workers. Systems are now being developed in a wide range of professional areas, from medical diagnosis to design. Recent demonstrations have already proved how well they can rival the expertise of humans.

A geology expert system developed by SRI International provides one illustration. The system was programmed using information obtained from interviews with nine expert geologists on the processes they follow in locating mineral deposits in the field. In a recent demonstration, the system was fed information on conditions in one area.

> After considering all the answers, the computer was able to pinpoint the ore in a small, unexplored area that was ringed by earlier borings and mines. SRI's expert system succeeded where humans failed because its capability to consider mind-boggling amounts of data far exceeded that of any flesh-and-blood expert (Business Week 1984b, 55).

Another area where expert systems have great potential is in the medical field. Here the knowledge base is large and constantly changing. Already the Chinese have developed such a system as a way of utilizing the vast knowledge accumulated from centuries of medical practice. One computer in Nanjing, China was programmed from the expertise of 3 prominent herbalists who were all in their 80s. After a doctor's assistant measures the patient's symptoms, the information is entered into the machine. The machine then diagnoses the illness and recommends treatment.

> What "Doc Computer" lacks in bedside manner, it more that compensates for in speed and effectiveness. In three years of practice two afternoons weekly, the machine has treated 6000 patients with what is reported to be a higher rate of recovery than ordinary physicians boast. The fee usually falls under $1 per visit, including the cost of medicinal herbs (San Francisco Examiner 1984).

Expert systems and other new technologies will make it easier for workers to access and process large amounts of information. Yet workers will not have to have more sophisticated skills to use these systems. To the contrary, the more sophisticated the technology, the easier it is to use. Just as new automobiles and stereos that incorporate sophisticated technologies require less not more skills to use, future devices in the workplace based on sophisticated technologies will require fewer skills to operate.

Whether the skill requirements of jobs rise or fall due to the increased use of new technologies will not only depend on the technical capabilities of these new machines, but how these machines are actually used in the workplace. If these technologies are used to further fragment work tasks, with machines increasingly performing more complex tasks, then skill requirements will likely decline. If, however, new machines enable workers to perform a wider range of tasks and they are given this latitude in using them, then skill requirements as well as productivity could actually increase (Levin 1984; Shaiken forthcoming, Chapter 6). Recent studies of the banking and insurance industries suggests that some recent technologies have been used in this way

(Appelbaum 1984; Adler forthcoming; Baron and Teegarden forthcoming). But future impacts will depend on the outcome of particular applications that result from both technical and social considerations.

The Composition of Jobs

While future technologies will be able to perform more complex mental tasks and reduce the skills required to use them, the skill requirements of jobs in the future will also depend on the composition of jobs in the economy. And that will depend on what jobs are displaced by machines and what sectors of the economy will grow in the future.

Just as employers have an economic incentive to fragment jobs into component parts in order to reduce labor costs, they also have an economic incentive to automate jobs that pay the highest wages. Thus expert systems and other sophisticated technologies are more likely to eliminate more skilled, high-salary jobs than less skilled, low-salary ones. The increased use of these devices will create new jobs in industries where they are manufactured and new jobs related to their use and maintenance. But recent employment projections for the U.S. suggest that few new jobs will be created in these areas.

Consider employment in firms where new technologies are developed and produced. Recent employment data from the U.S. Bureau of Labor Statistics indicate that only about 6 percent of the American workforce is currently employed in "high-tech" industries, based on a definition that covers 28 detailed industries from computer manufacturing to data processing services. These projections also suggest that only about 8 percent of the new jobs expected between 1982 and 1995 will be in these firms (Rumberger and Levin 1984, Table 3).

Employment projections do indicate that many jobs related to the use and maintenance of new technical devices, particularly computers, will experience rapid employment increases over this period. Jobs for computer service technicians, computer programmers, and computer operators are projected to be among the fastest growing jobs in the U.S. over the next decade. Yet because these jobs currently employ

relatively few people, these rapid growth rates will generate few new jobs, especially in comparison with more traditional clerical and service occupations. For instance, there will be more new jobs for janitors between 1982 and 1995--779,000--then there will be new jobs for computer service technicians, computer programmers, computer systems analysts, and computer operators combined (Rumberger and Levin 1984, Table 4)!

The increased use of new technologies is not expected to directly generate many new jobs in the U.S. economy in the near future. Rather future job growth will continue to be in more traditional areas where jobs were produced in the past. A comparison of projected employment growth within major occupation groups for the period 1982 to 1995 shows similar patterns to employment growth in the previous two decades (Table 3): employment in farming occupations will continue to decline, while the majority of new jobs will be in professional, clerical, and service occupations. Comparisons among the three periods reveal some surprising trends. For example, professional and technical occupations are expected to generate a smaller proportion of new jobs in the 1980s and 1990s (20 percent) than in either the 1960s (25 percent) or the 1970s (23 percent). At the other extreme, a small but increasing proportion of future jobs will be for laborers. Managerial employment is also expected to slow after increasing rapidly in the 1970s.

These projections, while by no means conclusive, suggest that the future economy in the United States is unlikely to shift toward an increasing proportion of high-skilled occupations. This contrasts with the situation in previous periods where employment growth tended to shift the average skill requirements of jobs upward. Since the increased use of advanced technologies could also reduce the skill requirements of many existing jobs, these two factors have the potential to lower the average skill requirements of future jobs.

Summary and Conclusions

Technology will have a widespread and profound impact on work in the future. One of those impacts will be to alter the skills that workers will require to perform their jobs. But will workers require more or fewer skills to perform their jobs in the future?

Although more detailed studies on the impact of new technologies on the skill requirements of jobs have yet to be done, existing studies suggest that technologies often reduce the skills workers require to perform their jobs. Moreover, employers have an economic incentive to eliminate high-skilled, high-wage jobs in order to cut labor costs. As further advances in micro-electronics lower the prices and increase the processing capabilities of future machines, they will be used to replace workers with more sophisticated skills. Current expert systems have already demonstrated the mental capabilities of new generation computers. And because the machines are so sophisticated, they make it easier for workers to use them.

Of course new jobs will be created for workers who design and build these new sophisticated devices. But recent employment projections indicate that relatively few new jobs will be created either in firms where these devices are built or in occupations related to their use (Rumberger and Levin 1984). Rather future job growth will continue to be dominated by retail trade and service employment, where there are a higher concentration of low-skill, low-wage jobs than in other sectors of the economy sector (Rumberger 1984b, Table 3). The net effect of these two trends will be to reduce the average skill requirements of jobs in the future job market.

One implication of this scenario is that current efforts to raise educational standards in the U.S. could produce a future generation of dissatisfied and unproductive workers. Recent evidence suggests that workers who have more education than their jobs require not only become dissatisfied, they are less productive (Rumberger 1981b, Chapter 5). A current imbalance between the education level of workers and the skill requirements of their jobs could explain some of the recent slowdown in productivity growth in the U.S. (Tsang 1984). This imbalance could

easily increase in the future, threatening the ability of the U.S. to compete in the world marketplace.

Technology not only affects the skill requirements of jobs, but also the control of work. As Braverman points out, fragmenting job tasks enables employers to better control the work process as well as lower labor costs. Technology can work in the same way. Along with the development of new information technologies have come new ways for employers to monitor the performance of their workers. New systems that greatly increase the productivity of telephone operators and insurance workers have already been developed, but the rigid monitoring has brought widespread complaints as well (New York Times 1983; Wall Street Journal 1983). Unions have now raised technology as an important bargaining issue.

The impact of technology on the skill requirements of jobs in the future is in no way predetermined. It will depend, in part, on the technologies that are developed. But it will also depend on how those technologies are used in the workplace. Although past technologies have often reduced the skills of workers and lessened their control over the work process, that does not have to be the case. In some firms, technology has been used to increase the discretion of workers, broaden the tasks they perform, and raise the skill requirements of their jobs (Levin 1982, 1984). Technology holds the promise of making work easier in the future and reducing the amount of work people have to perform in order to enjoy a high standard of living. The future challenge is to insure the promise of technology is achieved and the threat it poses is avoided.

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Table 1

Economic Output, Employment, and Output Per Worker
by Major Industry, 1947 and 1981

Industry Group	Economic Output[a]			Employment[b]			Output/Worker[c]	
	1947	1981	Change (%)	1947	1981	Change (%)	1947	1981
Agriculture	26.3	43.4	65	7.9	3.4	-60	3,329	12,765
Goods-producing								
Mining	10.8	22.3	106	1.0	1.1	18	11,309	19,700
Construction	22.9	52.0	127	2.0	4.2	110	11,450	12,381
Manufacturing	114.9	359.2	213	15.5	20.2	30	7,413	12,832
Services-producing								
Trans./Utilities	42.3	142.1	236	4.2	5.2	24	10,071	27,327
Trade	75.9	250.4	230	9.0	20.6	129	8,433	12,155
Fin./Insur./R.E.	54.7	243.6	345	1.7	5.3	212	32,176	45,962
Services	55.9	196.7	252	5.0	18.6	272	11,118	10,576
Government	68.7	178.1	159	5.5	16.0	191	12,491	11,131
TOTAL[d]	467.8	1477.2	216	57.0	100.4	76	8,207	14,713

[a]Billions of 1972 dollars.
[b]Millions of persons. Agriculture and TOTAL show all employed workers. Other categories show wage and salary workers only.
[c]1972 dollars.
[d]Economic output represented by gross domestic product.

Source: U.S. Council of Economic Advisors, Economic Report of the President (Washington, D.C.: U.S. Government Printing Office, 1984), Tables B-11, B-29, B-37.

Table 2

Employment Growth by Major Occupation Group,
1900 to 1980

(Millions of Jobs)

Major Occupation Group	1900-20	1920-40	1940-60	1960-80
White-collar	5.4	5.6	11.2	23.4
Professional and technical	1.0	1.6	3.5	8.5
Managers	1.1	1.0	1.7	4.1
Clerical	2.5	1.6	4.6	8.7
Sales	.8	1.4	1.4	2.1
Blue-collar	6.6	3.6	5.0	7.4
Craft	2.4	.7	3.0	4.2
Operatives	2.9	2.9	3.3	2.2
Laborers	1.3	---	-1.3	1.0
Service workers	.7	2.7	1.5	5.2
Farm workers	.5	-2.4	-4.9	-2.4

Note: Data for the 1900 to 1960 periods cover the experienced civilian labor force, 14 years old and over. Data for the 1960-80 period covers the employed population, 16 years old and over. Data not strictly comparable because of changes in the classification of occupations.

Sources: U.S. Bureau of the Census, Historical Statistics of the United States, Colonial Times to 1970, Bicentenial Edition, Part 1 (Washington, D.C.: U.S. Government Printing Office, 1975), Table D 127-141; U.S. Bureau of the Census, Statistical Abstract of the United States: 1984, 104th Edition (Washington, D.C.: U.S. Government Printing Office, 1983), Table 693.

Table 3

Employment Growth by Major Occupation Group,
1960 to 1995

(Percentage distribution)

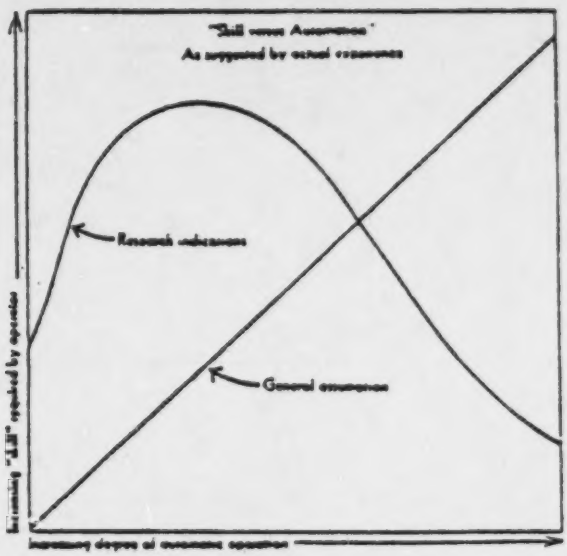
Major Occupation Group	1960-70	1970-80	1982-95
White-collar			
Professional and technical	25	23	20
Managers	8	14	10
Clerical	27	22	19
Sales	4	2	7
Blue-collar			
Craft	11	12	12
Operatives	13	1	9
Laborers	1	4	5
Service workers	11	17	17
Farm workers	--	--	--

Note: Data for the 1960 to 1980 periods cover the employed population, 16 years old and over and are derived from population surveys. Data for the 1982-95 period covers jobs and are derived from employer surveys.

Sources: U.S. Bureau of the Census, Statistical Abstract of the United States: 1984, 104th Edition (Washington, D.C.: U.S. Government Printing Office, 1983), Table 693; George T. Silvestri, John M. Lukasiewicz, and Marcus E. Einstein, "Occupational Employment Projections Through 1995," Monthly Labor Review, November 1983, Table 1.

Figure 1

The Relationship Between Increasing Levels of Automation and Job Skill Requirements



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